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Duane Arnold Energy Center

CEDAR RIVER OPERATIONAL ECOLOGICAL STUDY
ANNUAL REPORT

January 1992 - December 1992

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March 1993

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INTRODUCTION

This report presents the results of the physical, chemical, and biological studies of the Cedar River in the vicinity of the Duane Arnold Energy Center during the 19th year of station operation (January 1992 to December 1992).

The Duane Arnold Energy Center Operational Study was implemented in mid-January, 1974. Prior to plant start-up extensive preoperational data were collected from April, 1971 to January, 1974. These preoperational studies provided a substantial amount of "baseline" data with which to compare the information collected since the station became operational. The availability of the 19 years of operational data, collected under a variety of climatic and hydrological conditions, provides an excellent basis for the assessment of the effects of the operation of the Duane Arnold Energy Center on the limnology and water quality of the Cedar River. Equally important is the availability of sufficient data to identify long-term trends in the water quality of the Cedar River which are unrelated to station operation, but are indicative of climatic patterns, changes in land use practices, or pollution control procedures within the Cedar River basin.

SITE DESCRIPTION

The Duane Arnold Energy Center, a nuclear fueled electrical generating plant, operated by the Iowa Electric Light and Power Company, is located on the west side of the Cedar River, approximately two and one-half miles north-northeast of Palo, Iowa, in Linn County. The plant employs a boiling water nuclear power reactor which produces approximately 560 MWe of power (1650 MWth) at full capacity. Waste heat rejected from the turbine cycle to the condenser circulating water is removed by two closed loop induced draft cooling towers which require a maximum of 11,000 gpm (ca. 24.5 cfs) of water from the Cedar River. A maximum of 7,000 gpm (ca. 15.5 cfs) may be lost through evaporation, while 4,000 gpm (ca. 9 cfs) may be returned to the river as blowdown water from the cool side of the cooling towers.

OBJECTIVES

Studies to determine the baseline physical, chemical, and biological characteristics of the Cedar River near the Duane Arnold Energy Center prior to plant start-up were instituted in April of 1971. These preoperational studies are described in earlier reports.[1-3] Data from these studies served as a basis for the development of the operational study.

The operational studies were designed to identify and evaluate any significant effects of chemical or thermal discharges from the generating station into the Cedar River, as well as to assess the magnitude of impingement of the fishery on intake screens or entrainment in the condenser make-up water. These were first implemented in January, 1974 and have continued without interruption through the current year.[4-21]

The specific objectives of the operational study are twofold:

1. To continue routine water quality determinations in the Cedar River in order to identify any conditions which could result in environmental or water quality problems.
2. To conduct physical chemical, and biological studies in and downstream of the discharge canal and to compare the results with similar studies executed above the intake. This will make possible the determination of any water quality changes occurring as a result of chemical additions or condenser passage, and to identify any impacts of the plant effluent on aquatic communities downstream of the discharge.

STUDY PLAN

During the operational phase of the study sampling sites were established in the discharge canal and at four locations in the Cedar River (Figure 1): 1) upstream of the plant at the Lewis Access Bridge (Station 1); 2) directly upstream of the plant intake (Station 2); 3) at a point within the mixing zone approximately 140 feet downstream of the plant discharge (Station 3); and 4) adjacent to Comp Farm, located about one-half mile below plant (Station 4). Samples were also taken from the discharge canal (Station 5).

Prior to 1979, samples were collected and analyzed by the Department of Environmental Engineering of the University of Iowa. From January, 1979 through December, 1983 samples were collected and analyzed by Ecological Analysts, Inc. Since 1984 collection and analysis of samples has been conducted by the University of Iowa Hygienic Laboratory, located in Iowa City, Iowa. The conclusions contained in this annual report are based on the results of their analyses. Samples for routine physical, chemical, and biological analysis were taken twice per month, while other studies were conducted seasonally. The following are discussed in this report:

I. General Water Quality Analysis

A. Frequency: twice per month

B. Location: at all five stations

C. Parameters Measured:

1. Temperature
2. Turbidity
3. Solids (total, dissolved, and suspended)
4. Dissolved oxygen
5. Carbon dioxide
6. Alkalinity (total and carbonate)
7. pH
8. Hardness series (total and calcium)
9. Phosphate series (total and ortho)
10. Ammonia
11. Nitrate
12. Iron
13. Biochemical oxygen demand
14. Coliform series (fecal and *E. coli*)

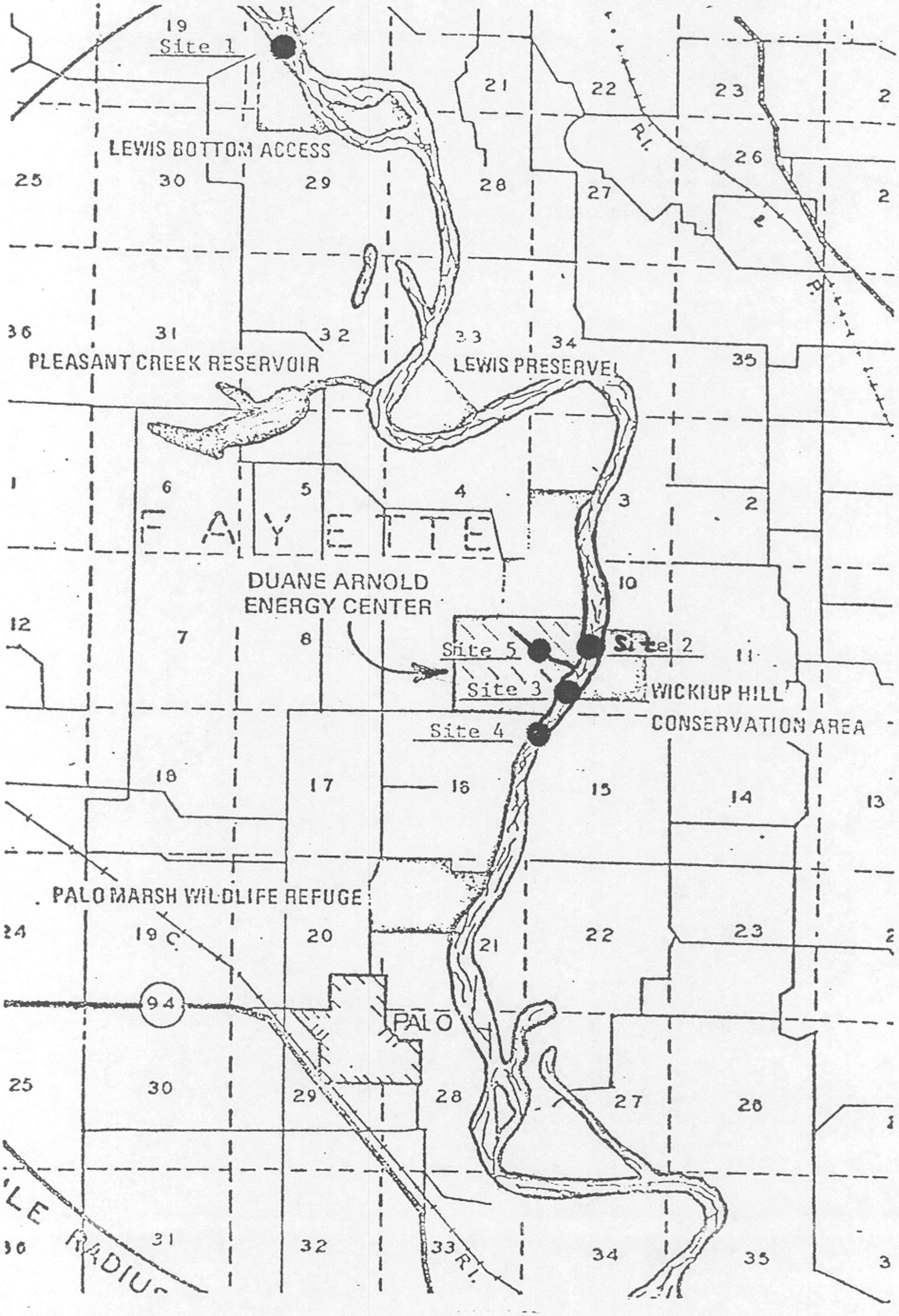

Figure 1. Location of Operational Sampling Sites

II. Additional Chemical Determinations

A. Frequency: twice yearly

B. Locations: at all five stations

C. Parameters Measured:

1. Chromium
2. Copper
3. Lead
4. Manganese
5. Mercury
6. Zinc
7. Chloride
8. Sulfate

III. Biological Studies

A. Benthic Studies:

1. Frequency: summer and fall
2. Location: at all five stations

B. Asiatic Clam (Corbicula) and Zebra Mussel (Dreissena) Surveys:

1. Frequency: twice yearly
2. Location: upstream and downstream of the plant, intake bay, cooling tower basin, and discharge canai. The Zebra mussel survey also included Pleasant Creek Reservoir.

C. Impingement Studies:

1. Frequency: daily
2. Location: intake structure

OBSERVATIONS

Physical Conditions

Hydrology (Table 1)

River flows during 1992 were substantially lower than those present in 1991. Mean monthly flows ranged from 84% of the 1951-1980 median monthly discharge in June to 534% in February. Estimated mean flow for the year was ca. 5,717 cfs, slightly higher than the average flow of ca. 4,836 cfs observed during the 21 year study. Mean monthly discharges at the Cedar Rapids gauging station ranged from 2,080 cfs in October to 12,740 cfs in March. Mean monthly discharges in 1992 were classified as excessive (greater than the 75% quartile) from January through March and in July, August, November, and December. Winter flows were relatively high ranging from 2,690 cfs in mid-January to 13,500 cfs on February 21. A maximum yearly daily discharge of 23,200 cfs occurred on March 14. Flows declined during mid-March through most of April but increased in late April to ca. 22,000 cfs. May and June flows were also substantially lower ranging from ca. 10,000 cfs in early May to 2,900 cfs in late June. Flows continued to decline through early July but increased to ca. 13,000 cfs by mid month. Flows declined steadily through August from ca. 6,000 to 2,200 cfs. September and October flows were near normal, ranging from a yearly low of 1,780 cfs on October 7 to ca. 3,600 cfs on September 20. November and December flows were well above average. A high late fall flow of 11,700 cfs was recorded on November 25. Hydrological data are summarized in Table 1.

Temperature (Table 2)

Ambient upstream river temperatures during 1992 ranged from 0.0°C (32.0°F) to 24.5°C (76.1°F). The maximum ambient (Station 1) temperature was observed on July 1. This value was identical to the 1991 level which was the lowest sine 1984[14] and well below the 1980 to 1991 average maximum of 27°C (81°F). Maximum downstream temperatures of 25.0°C (77°F) were observed at Station 3 and 4 also on July 1. The highest discharge canal (Station 5) temperature observed during the period was 29.0°C (84.2°F), which was also recorded on July 1. A maximum temperature differential (ΔT value) between the upstream river and the discharge canal (Station 2 vs. Station 5) of 18.0°C (32.4°F) was observed on November 18.

Station operation continued to have little effect on downstream water temperatures. The maximum ΔT value between ambient upstream temperatures at Station 2 and downstream temperatures at Station 3, located in the mixing zone for the discharge canal, of 1.0°C (1.8°F) was measured on October 1. A maximum temperature elevation at the Comp Farm station, one-half mile below the plant (Station 2 vs. Station 4) of 1.5°C (2.7°F) was observed on June 18. There was no instance in which a temperature elevation in excess of the Iowa water quality standard[22] of 3°C was observed. No other samples taken at Station 4 exhibited temperature differentials in excess of 1.0°C (1.8°F) above ambient. A summary of water temperature differentials between upstream and downstream locations is given in Table 3.

Turbidity (Table 4)

Average river turbidity values were the third highest observed during the 21 year study period, but still well below those present in 1991. Peak values of 200-220 NTU occurred at upstream river locations in late May. Low values (5-8 NTU) occurred during January. In contrast to most previous years, turbidity values in the discharge canal were occasionally higher than those observed in the upstream river. A maximum discharge canal turbidity of 370 NTU was observed on July 16.

Solids (Tables 5-7)

Solids determinations included total, dissolved, and suspended. Total solids values in upstream river samples were slightly lower than those observed in 1991.[21] Values ranges from 310 to 600 mg/L, with the majority falling between 400 and 450 mg/L.

Dissolved solids values were also somewhat lower than those present in 1991. Upstream values ranged from 170 to 380 mg/L. Values of less than 250 mg/L occurred at intervals in February and March and late August through September. High values continued to occur in the winter. As in 1991, dissolved solids values at Station 3, 140 feet downstream of the discharge canal, were only slightly higher than values observed upstream, and differences were less obvious than those present in 1989 and 1990. A maximum downstream value of 400 mg/L was observed at Station 3 on January 23.

Suspended solids values at river locations continued to be relatively high in 1992 ranging from 6 to 300 mg/L. Low values occurred in January while highest values occurred during periods of increasing flows in May and November.

As in previous years, total and dissolved solids values in the discharge canal were higher than in the river samples. Maximum total solids concentrations of 3,300 mg/L were observed in the discharge canal in mid-June, while a minimum value of 330 mg/L was observed on March 4.

Chemical Conditions

Dissolved Oxygen (Table 8)

Dissolved oxygen concentrations in river samples collected during 1992 continued to be high, ranging from 7.2 to 19.0 mg/L (77 to 130% saturation). Highest dissolved oxygen concentrations (ca. 11-19 mg/L) continued to occur in the river at intervals from January through April, and from October through December. Lowest values occurred in late May during a period of high runoff and increasing river flow.

Dissolved oxygen concentrations in the discharge canal (Station 5) ranged from 5.5 to 20.0 mg/L (70 to 137% saturation). Lowest values generally occurred from June through September. Highest values were observed in January and February.

<u>Carbon Dioxide</u> (Table 9)

Carbon dioxide concentrations were somewhat lower than those present in 1991,[21] ranging from <1 to 4 mg/L. From April through October values rarely exceeded 1 mg/L. Maximum levels (3-4 mg/L) usually occurred in January, February, and December.

<u>Alkalinity, pH, Hardness</u> (Tables 10-14)

These interrelated parameters were influenced by a variety of factors, including hydrological, climatic, and biological conditions. Average total alkalinity values in the 1992 river samples were similar to those present in 1990 and 1991.[20,21] Current values ranged from 106 to 254 mg/L. Lowest values occurred in February accompanying high river flows. Unlike the drought years of 1988 and 1989, lowest values did not occur during periods of low flow. Highest values occurred during January, November, and December.

Carbonate alkalinity was not present in river samples from January through March. A maximum value of 18 mg/L was observed in mid-October.

Values for pH in river samples were generally somewhat lower than those observed in 1990, ranging from 7.9 to 9.0. Highest values occurred from early September through October. As in previous years, highest levels accompanied increased photosynthetic activity while low values occurred during periods of runoff and high turbidity levels in February and May.

Total hardness values in the upstream river were similar to those present in 1991 and generally paralleled total alkalinity levels. The highest values (300-335 mg/L) occurred most frequently during January, November, and December, while low values of 150-155 mg/L occurred during a period of high river flow in February.

Hardness values in the discharge canal continued to be consistently higher during periods of station operation than upstream river values; a result of reconcentration in the blowdown. Total hardness levels in the discharge canal ranged from 155 to 1,210 mg/L. Levels downstream of the station however were not generally higher than upstream values.

Phosphates (Table 15 and 16)

Total phosphate concentrations in river samples were somewhat below 1991 levels[21] but were generally similar to those observed in 1990[20]. Concentrations in the upstream river ranged from <0.1 to 0.7 mg/L. High levels usually occurred during periods of high stream flow and runoff. Levels in the discharge canal were generally slightly higher than those observed in the river. Discharge canal values ranged from <0.1 to 2.5 mg/L.

Orthophosphate concentrations in river samples were usually less than 0.1 mg/L from mid-March through December. High values of 0.3 mg/L were present in February.

Ammonia (Table 17)

Average ammonia concentrations in the river were slightly lower than those present in 1991[21]. Concentrations were generally below detection limits (<0.1 mg/L as N) from April through early December. High concentrations, 0.7 to 0.8 mg/L (as N) occurred in late February.

Nitrate (Table 18)

Nitrate concentrations were lower than those present in 1991[21] but far higher than those present in the low flow years of 1988 and 1989.[18,19] During the current year nitrate values in upstream river samples ranged from 2.5 to 9.7 mg/L (as N). Maximum levels (8.5-9.7 mg/L as N) occurred in January, late March, and early December. Minimum levels (2.5-3.2 mg/L as N) occurred during September when flows were relatively low.

In contrast to 1990, nitrate concentrations were not consistently higher in the discharge canal than in river samples although occasional high levels were present. A maximum nitrate concentration of 29 mg/L (as N) was observed in the discharge canal on May 6. Downstream nitrate concentrations were generally similar to upstream levels ranging from 2.5 to 10 mg/L (as N).

Iron (Table 19)

Iron concentrations in the upstream were lower than those present during 1991[21]. Concentrations ranged from 0.15 to 2.0 mg/L. The maximum value was observed on May 20 accompanying increasing flows and high turbidity. Low values of 0.15 mg/L occurred on January 23. As in previous years, high iron concentrations were usually observed in association with increased turbidity and suspended solids, indicating that most of the iron present was in suspended form rather than in solution. Although occasional high concentrations were observed, iron levels were not consistently higher in the discharge canal during the current study. A maximum iron value of 4.7 mg/L was observed in the canal in mid-July. A minimum iron concentration of 0.19 mg/L was observed in the discharge canal on January 23.

Biological Studies

Biochemical Oxygen Demand (Table 20)

Average five day biochemical oxygen demand (BOD_5) values were slightly higher than those observed in 1990 and 1991 but substantially lower than those present in 1988 and 1989, averaging 5.5 mg/L in 1992 as compared to 9.6, 10.3, 4.8, and 4.3 mg/L in 1988, 1989, 1990, and 1991, respectively (Table 27). Levels in the river ranged from <1 to 18 mg/L. Highest values occurred in early September in association with large algal populations. Lowest values, <1-2 mg/L, occurred in January, March , November, and December. Relatively high BOD values, ranging from 10 to 12 mg/L, were also observed at intervals in July, August, and mid-October and also appeared to be related to algal blooms.

Coliform Organisms (Tables 21 and 22)

Coliform determinations included enumeration of both fecal coliforms as well as specific determination of Escherichia coli.

Coliform values were substantially lower than those present in 1991. Maximum river levels of fecal coliform and E. coli of 7,800 and 7,700 organisms/100 ml, respectively, were observed in early November during a period of rainfall and increasing river flow. Low values of 10 to 30 organisms/100 ml were observed in early May following an extended period of high river flow which probably washed many organisms from the basin. Fecal coliform and E. coli levels were only occasionally higher in the discharge canal (Station 5) than at upstream locations. Maximum fecal coliform and E. coli concentrations of 3,300 and 3,700 organisms/100 ml, respectively, were observed in samples from the discharge canal on July 16.

ADDITIONAL STUDIES

In addition to the routine monthly studies a number of seasonal limnological and water quality investigations were conducted during 1992. The studies discussed here include additional chemical determinations, benthic studies, asiatic clam (Corbicula) and zebra mussel (Dreissena) surveys, and impingement determinations.

Additional Chemical Determinations

Samples for additional chemical determinations were collected on April 1 and July 1 from all river locations and in the discharge canal and analyzed for chlorides, sulfates, chromium, copper, lead, manganese, mercury, and zinc. With few exceptions, concentrations of all parameters fell within the expected ranges and were similar to those observed during the previous year.

With the exception of manganese and copper, heavy metal values were below detection limits in the April samples. Manganese values were low ranging from 30 to 40 ug/L. Copper concentrations were relatively high at all locations ranging from 30 to 50 ug/L. Two of the river samples one upstream and one downstream of the station exceeded the chronic criteria for copper of 35 ug/L for Class B warm waters[22]. Copper values were lower in the July samples but very high zinc levels of 900 ug/L were present in the discharge canal. Other heavy metal concentrations remained low and no violations of water quality standards for heavy metals were observed.[22]

Reconcentration of solids in the blowdown did not result in increases in sulfate or chloride samples from the discharge canal on April 1 but substantial increases were present on July 1. However downstream increases were minimal on both sampling dates. The high sulfate levels frequently present in the discharge canal are due largely to the addition of sulfuric acid for pH control in the cooling water. The results of additional chemical determinations are given in Table 23.

Benthic Studies

Artificial substrate samplers (Hester-Dendy) were placed at each of the four sampling locations upstream and downstream of the station and in the discharge canal on May 20 and August 20, 1992. These substrates were collected on July 1 and October 1, 1992 following a six week period to allow for the development of a benthic community.

As in previous years, the communities which developed on the substrates were far larger and more diverse than those which occur on the shifting sand and silt bottom characteristic of the Cedar River in the vicinity of the Duane Arnold Energy Center. A total of 27 taxa were identified during the two sampling periods, 25 in July and 23 in October. These included 24 species (6 orders) of insects, one specie of snail, one specie of annelid, and one specie of flatworm. Both the May-July, and August-October river substrate communities were dominated by chironomid (midge) larvae. Discharge canal substrates continued to exhibit far fewer organisms and much lower diversity than did river substrates. Physa (snails) were the dominant organisms observed on the discharge canal substrates.

In general, there continued to be little difference in the overall composition of the benthic populations between upstream and downstream locations, although the number of organisms varied considerably.

The total numbers of organisms were substantially higher at the upstream (Lewis Access) location on the August-October substrate while on the May-July substrates somewhat higher numbers were present at the upstream DAEC station. Random differences in the number of organisms at the various locations has been observed during past studies and no consistent pattern has been apparent.

As in previous years, the artificial substrate studies indicate the Cedar River, both upstream and downstream of the Duane Arnold Energy Center, is capable of supporting a relatively diverse macroinvertebrate fauna in those limited areas where suitable bottom habitat is available. The results of the benthic studies are given in Table 24.

Asiatic Clam and Zebra Mussel Surveys

In past years several power generation facilities have experienced problems with blockage of cooling water intake systems by large numbers of asiatic clams (Corbicula sp.). Although this clam is common in portions of the Iowa reach of the Mississippi River, it is normally absent from areas with shifting sand/silt substrates such as occur in the Cedar River in the vicinity of the Duane Arnold Energy center. Corbicula has not been collected from the Cedar River in the vicinity of the DAEC during the routine monitoring program, which was implemented in April of 1971. A single Corbicula was, however, collected in January of 1979 in the vicinity of Lewis Access, upstream of DAEC, by Hazelton personnel. Because Corbicula has been collected on one occasion from the Cedar River and is commonly found in power plant intakes on the Mississippi River, studies were implemented at the Duane Arnold Energy Center in 1981 to determine if the organism was present in the vicinity of the station or had established itself within the system. No Corbicula were collected during the 1981 to 1991 investigations.

The zebra mussel (Dreissena polymorpha) is a European form which was first found in the United States in Lakes St. Clair and Erie in 1988. It is likely this clam entered the St. Lawrence Seaway from ships that used fresh water from Europe as a ballast and then dumped the water when they reached the United States. The mussel is now found in all of the Great Lakes and in 1991, just three years after they were first found in the U.S., they have been collected in the Hudson, Illinois, Mississippi, Ohio, Susquehanna, Tennessee, and Cumberland Rivers.[23] The zebra mussel has been a major problem in water intakes in Europe for many years and is now causing significant problems at many power plant intakes as well as a number of municipal water treatment plants in the United States. The organisms tend to grow in clumps attached to a solid substrate and can rapidly clog intake structures, screens, and pipes. It is difficult to control chemically and frequently must be removed mechanically. The mussel is adapted to both river and lake habitats and does especially well in enriched waters which support large plankton populations that it utilizes as food. Unlike the asiatic clam (Corbicula), it is capable of living in cold waters and does not require a silty substrate. Although it is impossible to make exact estimates, it will doubtlessly continue to increase its range during the next few years. If, or more likely when, it does colonize Iowa tributaries to the Mississippi River, problems with intake structures at power plants in the area are likely to occur. As a result of these concerns, studies designed to detect the presence of the Zebra mussel were first instituted in 1990. No zebra mussels were found during either 1990 or 1991.

In 1992 samples were collected in May, September, and October in the discharge canal and at river locations upstream and downstream of the station, using a mussel rake and/or Ponar dredge and examined for the presence of both the asiatic clam and the zebra mussel. The intake bay, between the bar racks and the traveling screens, and the collection basin of the cooling tower were also inspected along with the shoreline and littoral area around the discharge structure at Pleasant Creek Lake. None of the surveys conducted during 1992 revealed the presence of either species.

Impingement Studies

The total numbers of fish impinged on the intake screens at the Duane Arnold Energy Center during 1992, as reported by Iowa Electric personnel, was the lowest observed since 1987. Daily counts conducted by DAEC station personnel indicated a total of 532 fish were impinged during 1992. Highest impingement rates continued to occur during the winter and early spring period. During the months of January to April and in December 477 fish, or approximately 90% of the yearly impingement total, were removed from the trash baskets. Lowest impingement rates occurred in August and September when only 4 fish were removed from the trash baskets. The month with the highest impingement rate was April, when 163 fish were collected in the trash baskets. The results of the daily trash basket counts are given in Table 25.

DISCUSSION AND CONCLUSIONS

In contrast to the drought and low river flow which characterized 1988 and 1989, and the extremely high flows present in 1991 flows in the Cedar River during 1992 were only slightly above normal and similar to those present in 1990. Even during the low flow years of 1988 and 1989 as well as during the high flow year of 1991 the impact of station operation on the water quality of the Cedar River was low. This pattern continued during the current year. In 1992 the average temperature differential (ΔT) between upstream and downstream locations (Station 2 vs. Station 3) during periods of station operation was only 0.2°C (0.4°F). This value is even lower than the average differential of 0.4°C (0.7°F) present in 1991. The maximum observed ΔT (Station 2 vs. Station 3) in 1992 was only 1.0°C (1.8°F), well below the 1988 and 1989 maximum differentials of 4.0 and 3.5°C (7.2 and 6.3°F), respectively and slightly below the 1991 maximum differential of 1.5°C (2.7°F). Obviously no temperature differentials in excess of the 3°C (5.4°F) water quality standard[22] were observed during 1992. Other parameters, such as dissolved solids, hardness, and nitrates which are increased by reconcentration in the blowdown, also continued to exhibit no or only minimal increases at the downstream locations (Table 26).

During 1992 there were no incidents where an exceedence of the applicable Iowa water quality standards were observed which could be attributed to the operation of the Duane Arnold Energy Center. On April 1, 1992, copper concentrations slightly in excess of the Iowa water quality standard of 35 ug/L, the chronic criteria for Class B warm waters[22], were observed in both discharge canal and river samples. However since elevated values were present at both upstream and downstream locations they are not attributable to the station and do not constitute a violation of the Iowa water quality standards.

Although station operation had minimal impact on the water quality of the Cedar River, the effects of hydrological and climatic conditions as well as agricultural activities were evident. This was especially true when the results of the current study are compared to those of 1988 and 1989, when flows were well below normal and in 1991 when high flows were present. As expected, sediment and agricultural runoff related parameters exhibited their highest levels during 1991 when turbidity, suspended solids, nitrate, iron, and fecal coliform values at the upstream (Station 1) river location averaged 65 NTU, 96 mg/L, 7.9 mg/L (as N), 1.03 mg/L, and 1,247 organisms/100 ml, respectively. These compare to the low flow years when 1988 averages of 28 NTU, 63 mg/L, 2.8 mg/L (as N), 0.34 mg/L, and 214 organisms/100 ml, and 1989 averages of 24 NTU, 54 mg/L, 1.5 mg/L (as N), 0.24 mg/L, and 79 organisms/100 ml were recorded. In 1992 average values for the above mentioned parameters all fell between values observed during the low and high flow periods when average turbidity values of 49 NTU, suspended solids of 90 mg/L, iron of 0.62 mg/L, nitrates of 6.4 mg/L (as N), and fecal coliforms of 790 organisms/100 ml were present. An analysis of average yearly values for several parameters and mean yearly flows since the inception of the study (Table 27) indicates a similar relationship between river discharge and water quality. These contrasts are even more apparent when the relative loading values, obtained by multiplying the average annual concentration by annual cumulative runoff, are compared (Table 28).

As expected, the operation of the Duane Arnold Energy Center during 1992 continued to have a minimal impact on aquatic organisms in the Cedar River adjacent to the station. The benthic community of the Cedar River in the vicinity of the Duane Arnold Energy Center has consistently been characterized by low diversity and productivity throughout the entire study period. This condition is unrelated to either station operation or poor water quality, but rather to the nature of the river bottom which is characterized by a shifting sand and silt substrate that is not conducive to the development of a diverse or productive benthic community. However when artificial substrates (Hester-Dendy) are place in the Cedar River, they develop populations which are characterized by relatively high species diversity and many organisms indicative of relatively good water quality. This pattern continued during 1992 when artificial substrates at upstream and downstream locations exhibited generally similar species composition and diversity in both the May-July and August-October studies. Although the total number of organisms were substantially higher at the upstream (Lewis Access) location during the August-October study this difference did not appear to be related to station operation but rather to the presence of large numbers of chironomid (midge) larvae, a tolerant form which frequently occurs in large localized population. Differences in population densities were minimal during the May-July studies. Random variations in total number of organisms developing on the substrates has been characteristic of past studies and no consistent differences between upstream and downstream populations have been observed.

In contrast, the discharge canal substrates exhibited substantially lower diversity and total numbers on both sampling dates. This pattern has frequently been evident in earlier studies, [17,18,20,21] indicating that the discharge canal provides a less suitable environment for benthic biota. This does not, however, appear to be affecting populations downstream, and the current artificial substrate studies continue to indicate that the operation of the Duane Arnold Energy Center has a minimal impact on the benthic community of the Cedar River.

During 1992 a total of 532 fish were impinged on the intake screens at the Duane Arnold Energy Center. This total is well below the numbers present in 1990 and 1991, and substantially less than the record number of 4,933 recorded in 1989. Most of the impingement continued to occur during the winter and early spring period. Increased impingement rates during the winter period appear to be related to the recirculation of warm water into the intake for deicing purposes, which attracts fish to the area and are subsequently impinged. Impingement rates continue to be extremely low and the impact of impingement on the fishery of the Cedar River, is insignificant.

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22. State of Iowa, "Water Quality Standards." Chapter 61, 567, Iowa Administrative Code. State of Iowa, Des Moines, Iowa, April 1990.

23. U.S. Army Corps of Engineers, "The Zebra Mussel: Biology, Ecology and Recommended Control Strategies." Tech. Note ZMR-1-01, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, March 1992.

Table 1

Summary of Hydrological Conditions
Cedar River at Cedar Rapids*
1992

Date	Mean Monthly Discharge cfs	Percent of Median Discharge†
January	3984	381**
February	6514	534**
March	12,740	240**
April	9449	162
May	6005	140
June	3571	84
July	6302	192**
August	3765	187**
September	2636	148
October	2080	84
November	6463	262**
December	5095	270**

*Data obtained from U.S. Geological Survey records
**In excess of the 75% quartile
†Data for January-September based on median discharge for 1951-1980.
Data for October-December based on median discharge for 1961-1990.

Table 2

Temperature (°C) Values for the Cedar River near the Duane Arnold Energy Center During 1992

	Sampling Locations				
Date 1992	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-08	3.0	3.0	3.5	3.0	3.0
Jan-23	0.0	0.0	0.0	0.0	0.0
Feb-05	0.0	0.0	0.0	0.0	0.0
Feb-20	1.0	1.5	1.5	1.5	1.5
Mar-04	5.0	5.0	6.5	5.0	5.0
Mar-19	4.0	4.0	6.5	4.5	4.5
Apr-01	5.5	6.0	9.0	6.0	6.0
Apr-16	10.5	10.5	11.5	10.5	11.0
May-06	14.0	15.0	20.0	15.0	16.0
May-20	19.5	19.5	28.0	20.0	20.0
Jun-04	21.5	23.5	28.0	23.0	23.0
Jun-18	23.0	23.0	27.0	23.5	24.5
Jul-01	24.5	24.5	29.0	25.0	25.0
Jul-16	21.5	22.0	28.0	22.0	22.0
Aug-06	20.5	21.5	25.0	21.0	21.0
Aug-20	20.0	20.0	17.5	20.0	21.0
Sep-03	19.0	19.5	19.5	20.0	20.5
Sep-16	21.5	21.5	28.5	22.0	22.0
Oct-01	15.0	15.5	25.0	16.5	16.5
Oct-14	10.5	11.0	19.0	11.5	12.0
Nov-05	4.0	4.0	16.5	4.0	4.5
Nov-18	4.0	5.5	23.5	5.0	5.0
Dec-03	0.5	0.5	1.5	0.5	0.5
Dec-16	2.0	2.0	4.0	2.0	2.0

Table 3

Summary of Water Temperature Differentials
and Station Output During Periods of
Cedar River Sampling in 1992

Date	ΔT(°C) Upstream River (Sta. 2) vs. Discharge (Sta. 5)	ΔT(°C) Upstream River (Sta. 2) vs. Downstream River (Sta. 3)	ΔT(°C) Upstream River (Sta. 2) vs. Downstream River (Sta. 4)	Station Output (% Full Power)
Jan-08	0.5	0.0	0.0	89
Jan-23	0.0	0.0	0.0	84
Feb-05	0.0	0.0	0.0	80
Feb-20	0.0	0.0	0.0	75
Mar-04	1.5	0.0	0.0	0
Mar-19	2.5	0.5	0.5	0
Apr-01	3.0	0.0	0.0	0
Apr-16	1.0	0.0	0.0	0
May-06	5.0	0.0	1.0	96
May-20	8.5	0.5	0.5	100
Jun-04	4.5	-0.5	-0.5	100
Jun-18	4.0	0.5	1.5	100
Jul-01	4.5	0.5	0.5	100
Jul-16	6.0	0.0	0.0	100
Aug-06	4.5	-0.5	-0.5	100
Aug-20	2.5	0.0	1.0	0
Sep-03	0.0	0.5	1.0	20
Sep-16	7.0	0.5	0.5	100
Oct-01	9.5	1.0	1.0	89
Oct-14	8.0	0.5	1.0	100
Nov-05	12.5	0.0	0.5	100
Nov-18	18.0	-0.5	-0.5	78
Dec-03	1.0	0.0	0.0	100
Dec-16	2.0	0.0	0.0	100

Table 4

Turbidity (NTU) Values for the Cedar River
near the Duane Arnold Energy Center During 1992

	Sampling Locations				
Date 1992	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-08	11	11	11	11	11
Jan-23	8	5	6	7	6
Feb-05	43	49	48	49	48
Feb-20	120	130	120	120	130
Mar-04	35	37	42	38	38
Mar-19	28	29	25	28	29
Apr-01	18	18	13	18	17
Apr-16	16	17	15	17	17
May-06	38	38	89	36	34
May-20	200	220	200	210	220
Jun-04	48	47	110	51	42
Jun-18	40	42	78	40	42
Jul-01	51	51	120	56	58
Jul-16	110	96	370	98	99
Aug-06	54	55	140	56	52
Aug-20	50	50	54	51	48
Sep-03	47	46	33	47	47
Sep-16	39	44	90	44	40
Oct-01	21	23	28	26	26
Oct-14	16	21	54	17	18
Nov-05	110	110	150	97	110
Nov-18	11	11	30	12	13
Dec-03	13	15	8	16	16
Dec-16	28	26	10	29	26

Table 5

Total Solids (mg/L) Values for the Cedar River near the Duane Arnold Energy Center During 1992

Date 1992	Sampling Locations: Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-08	410	410	420	420	430
Jan-23	410	430	450	440	440
Feb-05	380	390	410	400	400
Feb-20	400	400	380	400	390
Mar-04	310	310	330	310	320
Mar-19	400	400	370	410	410
Apr-01	420	420	380	410	410
Apr-16	390	410	390	400	400
May-06	420	410	1900	420	420
May-20	580	590	1900	580	590
Jun-04	410	430	2000	420	420
Jun-18	430	430	3300	460	440
Jul-01	430	430	2200	420	450
Jul-16	470	470	1700	470	480
Aug-06	440	440	2000	450	460
Aug-20	390	380	400	380	380
Sep-03	350	330	340	350	360
Sep-16	350	350	1700	350	390
Oct-01	410	390	1700	430	400
Oct-14	390	390	1600	410	410
Nov-05	580	600	1700	560	530
Nov-18	420	410	1400	450	430
Dec-03	400	420	530	430	430
Dec-16	440	430	760	420	420

Table 6

Dissolved Solids (mg/L) Values for the Cedar River near the Duane Arnold Energy Center During 1992

Date 1992	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	Sampling Locations				
	1	2	5	3	4
Jan-08	350	360	400	370	360
Jan-23	380	380	400	400	380
Feb-05	260	290	240	300	290
Feb-20	170	170	180	170	180
Mar-04	220	220	220	220	220
Mar-19	330	330	320	330	320
Apr-01	340	340	332	350	340
Apr-16	330	330	320	300	330
May-06	300	300	1600	310	300
May-20	250	260	1500	260	250
Jun-04	290	280	1700	300	300
Jun-18	280	280	1400	320	300
Jul-01	260	260	1700	260	260
Jul-16	290	270	1100	270	280
Aug-06	310	280	1600	300	280
Aug-20	230	220	250	220	220
Sep-03	220	210	240	220	180
Sep-16	240	240	1500	230	270
Oct-01	300	290	1500	360	300
Oct-14	320	320	1400	330	340
Nov-05	310	310	1400	320	330
Nov-18	380	370	1200	370	360
Dec-03	360	360	450	370	380
Dec-16	340	320	730	310	320

Table 7

Suspended Solids (mg/L) Values for the Cedar River near the Duane Arnold Energy Center During 1992

Date 1992	Sampling Locations: Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-08	19	18	8	18	18
Jan-23	9	6	8	8	8
Feb-05	57	64	63	72	70
Feb-20	210	200	180	200	200
Mar-04	49	53	64	52	55
Mar-19	47	47	36	47	46
Apr-01	33	34	17	35	34
Apr-16	30	33	30	33	33
May-06	80	79	130	77	72
May-20	290	300	240	290	290
Jun-04	87	97	160	96	88
Jun-18	100	100	150	100	100
Jul-01	100	100	210	110	120
Jul-16	160	160	500	170	160
Aug-06	100	98	190	110	96
Aug-20	110	110	110	110	110
Sep-03	120	110	88	130	130
Sep-16	110	130	170	100	120
Oct-01	60	52	110	76	80
Oct-14	61	59	96	66	55
Nov-05	230	220	230	240	210
Nov-18	18	17	42	20	17
Dec-03	24	23	8	24	20
Dec-16	52	50	9	54	52

Table 8

Dissolved Oxygen (mg/L) Values for the Cedar River near the Duane Arnold Energy Center During 1992

	Sampling Locations				
Date 1992	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-08	18.4	15.0	16.3	14.8	16.4
Jan-23	15.0	14.8	14.2	14.0	14.0
Feb-05	16.9	18.0	20.0	17.9	19.0
Feb-20	12.3	11.7	13.2	12.5	12.3
Mar-04	11.0	10.7	11.6	10.8	10.8
Mar-19	13.8	13.5	13.1	13.4	12.4
Apr-01	13.5	14.6	13.1	14.0	14.1
Apr-16	14.0	14.2	13.7	14.0	14.0
May-06	11.0	11.4	8.9	11.3	12.0
May-20	7.2	8.2	7.1	7.8	8.1
Jun-04	11.8	12.2	7.0	11.4	13.0
Jun-18	8.3	9.0	6.6	9.4	10.0
Jul-01	10.6	12.0	7.3	12.7	13.5
Jul-16	8.4	8.6	7.7	8.6	10.6
Aug-06	9.6	10.4	7.0	10.5	11.0
Aug-20	11.2	12.4	9.6	11.9	13.6
Sep-03	11.6	13.0	9.8	12.6	14.8
Sep-16	10.0	12.4	5.5	12.3	13.3
Oct-01	13.3	14.0	7.8	14.6	16.4
Oct-14	12.6	13.3	8.3	12.6	14.0
Nov-05	12.6	13.1	9.0	12.0	12.8
Nov-18	12.3	12.1	7.2	12.0	12.2
Dec-03	13.5	13.3	10.2	13.2	13.3
Dec-16	12.2	12.8	9.1	12.0	12.8

Table 9

Carbon Dioxide (mg/L) Values for the Cedar River near the Duane Arnold Energy Center During 1992

	Sampling Locations				
Date 1992	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-08	3	3	3	3	3
Jan-23	4	3	4	4	4
Feb-05	3	3	3	3	3
Feb-20	2	3	2	3	3
Mar-04	3	3	3	2	3
Mar-19	3	3	3	3	3
Apr-01	<1	<1	3	<1	<1
Apr-16	<1	<1	<1	<1	<1
May-06	<1	<1	*	<1	<1
May-20	4	3	*	3	3
Jun-04	<1	<1	*	<1	<1
Jun-18	1	1	*	1	1
Jul-01	<1	<1	*	<1	<1
Jul-16	2	2	*	3	2
Aug-06	2	2	*	2	<1
Aug-20	<1	<1	<1	<1	<1
Sep-03	<1	<1	<1	<1	<1
Sep-16	<1	<1	*	<1	<1
Oct-01	<1	<1	*	<1	<1
Oct-14	<1	<1	*	<1	<1
Nov-05	3	3	*	3	3
Nov-18	<1	<1	*	<1	<1
Dec-03	<1	<1	6	<1	<1
Dec-16	3	3	21	3	3

*Unable to calculate

Table10

Total Alkalinity (mg/L-$CaCO_3$) Values for the Cedar River near the Duane Arnold Energy Center During 1992

	Sampling Locations				
Date 1992	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-08	218	212	202	218	220
Jan-23	246	218	234	244	246
Feb-05	186	184	180	188	188
Feb-20	106	114	102	122	116
Mar-04	130	136	136	122	134
Mar-19	206	206	214	210	214
Apr-01	218	208	220	210	214
Apr-16	212	208	212	216	214
May-06	210	192	94	194	198
May-20	168	156	156	152	154
Jun-04	188	184	126	186	184
Jun-18	170	164	120	174	144
Jul-01	158	158	102	152	146
Jul-16	182	174	120	192	184
Aug-06	190	190	124	190	194
Aug-20	138	136	162	144	150
Sep-03	132	126	122	126	124
Sep-16	136	148	118	144	138
Oct-01	188	182	114	180	178
Oct-14	200	196	158	196	198
Nov-05	210	208	140	214	206
Nov-18	246	254	146	248	250
Dec-03	238	244	200	242	244
Dec-16	220	212	160	210	200

Table11

Carbonate Alkalinity (mg/L-$CaCO_3$) Values for the Cedar River near the Duane Arnold Energy Center During 1992

Date 1992	Sampling Locations: Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-08	<1	<1	<1	<1	<1
Jan-23	<1	<1	<1	<1	<1
Feb-05	<1	<1	<1	<1	<1
Feb-20	<1	<1	<1	<1	<1
Mar-04	<1	<1	<1	<1	<1
Mar-19	<1	<1	<1	<1	<1
Apr-01	6	4	<1	6	6
Apr-16	8	8	4	8	8
May-06	8	12	<1	8	14
May-20	<1	<1	<1	<1	<1
Jun-04	6	6	<1	8	8
Jun-18	<1	<1	6	<1	<1
Jul-01	4	8	<1	8	8
Jul-16	<1	<1	<1	<1	<1
Aug-06	<1	<1	<1	<1	6
Aug-20	8	8	6	4	16
Sep-03	4	5	2	14	16
Sep-16	<1	10	<1	10	10
Oct-01	5	8	<1	9	11
Oct-14	8	12	<1	12	18
Nov-05	<1	<1	<1	<1	<1
Nov-18	8	8	<1	8	7
Dec-03	6	4	<1	4	8
Dec-16	<1	<1	<1	<1	<1

Table12

Units of pH Values for the Cedar River
near the Duane Arnold Energy Center During 1992

Date 1992	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	Sampling Locations				
	1	2	5	3	4
Jan-08	8.3	8.3	8.2	8.3	8.3
Jan-23	8.2	8.2	8.2	8.2	8.2
Feb-05	8.1	8.2	8.2	8.2	8.2
Feb-20	8.1	8.0	8.1	8.1	8.0
Mar-04	8.1	8.1	8.1	8.1	8.1
Mar-19	8.3	8.3	8.3	8.2	8.3
Apr-01	8.4	8.4	8.3	8.5	8.5
Apr-16	8.5	8.5	8.4	8.5	8.5
May-06	8.5	8.6	7.7	8.6	8.6
May-20	7.9	8.0	8.0	8.0	8.0
Jun-04	8.5	8.6	7.8	8.6	8.6
Jun-18	8.4	8.4	8.0	8.4	8.4
Jul-01	8.4	8.5	7.8	8.6	8.6
Jul-16	8.1	8.1	7.8	8.1	8.1
Aug-06	8.3	8.3	7.7	8.3	8.4
Aug-20	8.5	8.5	8.4	8.6	8.7
Sep-03	8.7	8.9	8.7	8.9	9.0
Sep-16	8.3	8.7	7.8	8.7	8.7
Oct-01	8.6	8.7	7.9	8.7	8.8
Oct-14	8.4	8.5	7.9	8.5	8.6
Nov-05	8.2	8.2	7.8	8.2	8.3
Nov-18	8.5	8.4	7.9	8.5	8.4
Dec-03	8.4	8.4	8.0	8.4	8.4
Dec-16	8.3	8.3	7.3	8.3	8.2

Table13

Total Hardness (mg/L-$CaCO_3$) Values for the Cedar River near the Duane Arnold Energy Center During 1992

	Sampling Locations				
Date 1992	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-08	310	300	330	315	300
Jan-23	316	324	338	352	328
Feb-05	250	265	310	310	255
Feb-20	155	150	155	165	155
Mar-04	185	180	190	205	195
Mar-19	280	280	275	305	290
Apr-01	300	295	300	295	300
Apr-16	300	290	310	300	295
May-06	280	270	1210	300	305
May-20	245	235	1060	235	235
Jun-04	260	250	1210	270	279
Jun-18	250	245	935	265	245
Jul-01	242	243	1160	243	217
Jul-16	250	255	780	255	260
Aug-06	275	265	1130	265	320
Aug-20	220	220	230	215	205
Sep-03	195	195	215	190	185
Sep-16	175	200	960	190	195
Oct-01	270	260	1060	280	270
Oct-14	310	280	950	310	310
Nov-05	295	275	925	275	280
Nov-18	305	335	875	330	315
Dec-03	310	320	400	320	310
Dec-16	285	285	535	295	325

Table14

Calcium Hardness (mg/L-$CaCO_3$) Values for the Cedar River near the Duane Arnold Energy Center During 1992

Date 1992	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	Sampling Locations				
	1	2	5	3	4
Jan-08	210	215	210	220	210
Jan-23	225	220	235	245	222
Feb-05	190	170	210	210	225
Feb-20	105	100	110	110	110
Mar-04	135	125	125	130	130
Mar-19	200	200	190	190	200
Apr-01	210	210	205	200	200
Apr-16	200	200	215	210	195
May-06	170	190	772	200	205
May-20	160	155	675	160	165
Jun-04	160	158	742	179	183
Jun-18	160	130	541	170	145
Jul-01	120	114	667	111	105
Jul-16	180	170	530	170	165
Aug-06	175	170	777	175	185
Aug-20	110	90	120	105	105
Sep-03	110	115	100	95	90
Sep-16	105	110	580	95	110
Oct-01	149	140	661	160	130
Oct-14	120	90	610	80	120
Nov-05	185	180	600	185	190
Nov-18	225	230	615	230	230
Dec-03	230	210	270	230	240
Dec-16	210	210	385	215	205

Table 15

Total Phosphorus (mg/L-P) Values for the Cedar River near the Duane Arnold Energy Center During 1992

Date 1992	Sampling Locations: Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-08	0.4	0.3	0.2	0.4	0.2
Jan-23	0.3	0.3	0.2	0.2	0.2
Feb-05	0.8	0.7	0.8	0.8	0.8
Feb-20	0.4	0.7	0.8	0.8	0.9
Mar-04	0.4	0.5	0.4	0.4	0.4
Mar-19	0.6	0.6	0.1	0.2	0.1
Apr-01	0.2	0.2	0.5	0.2	0.1
Apr-16	<0.1	<0.1	<0.1	<0.1	<0.1
May-06	0.2	0.1	2.0	0.2	0.2
May-20	0.5	0.5	2.0	0.6	0.5
Jun-04	0.1	0.1	2.0	0.1	0.1
Jun-18	0.2	0.2	1.7	0.2	0.2
Jul-01	0.3	0.4	2.2	0.3	0.3
Jul-16	0.4	0.4	2.5	0.4	0.4
Aug-06	0.2	0.2	2.1	0.2	0.2
Aug-20	0.2	0.2	0.8	0.3	0.2
Sep-03	0.2	0.2	0.3	0.2	0.2
Sep-16	0.3	0.2	1.9	0.2	0.2
Oct-01	0.2	0.2	1.7	0.2	0.2
Oct-14	0.2	0.2	1.6	0.2	0.2
Nov-05	0.4	0.4	2.0	0.4	0.2
Nov-18	0.4	0.4	0.9	0.4	0.4
Dec-03	0.4	0.4	0.6	0.4	0.4
Dec-16	<0.1	<0.1	0.4	<0.1	0.1

Table 16

Soluble Orthophosphate (mg/L-P) Values for the Cedar River near the Duane Arnold Energy Center During 1992

	Sampling Locations				
Date 1992	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-08	0.2	0.3	0.1	0.2	0.1
Jan-23	0.2	0.2	0.1	0.1	0.2
Feb-05	0.2	0.2	0.2	0.2	0.2
Feb-20	0.3	0.3	0.3	0.3	0.3
Mar-04	0.2	0.2	0.2	0.2	0.2
Mar-19	0.1	0.1	0.1	0.1	0.1
Apr-01	<0.1	<0.1	<0.1	<0.1	<0.1
Apr-16	<0.1	<0.1	<0.1	<0.1	<0.1
May-06	<0.1	<0.1	0.5	<0.1	<0.1
May-20	<0.1	<0.1	0.6	<0.1	<0.1
Jun-04	<0.1	<0.1	0.6	<0.1	<0.1
Jun-18	<0.1	<0.1	0.6	<0.1	<0.1
Jul-01	0.2	<0.1	<0.1	<0.1	<0.1
Jul-16	0.2	0.2	0.9	0.2	0.2
Aug-06	<0.1	<0.1	0.8	<0.1	<0.1
Aug-20	<0.1	<0.1	<0.1	0.2	0.2
Sep-03	<0.1	<0.1	<0.1	<0.1	<0.1
Sep-16	<0.1	<0.1	0.8	<0.1	<0.1
Oct-01	<0.1	<0.1	0.7	0.1	<0.1
Oct-14	0.1	<0.1	0.4	<0.1	<0.1
Nov-05	0.2	0.2	0.6	0.2	0.2
Nov-18	<0.1	<0.1	<0.1	<0.1	<0.1
Dec-03	<0.1	<0.1	0.1	<0.1	<0.1
Dec-16	<0.1	<0.1	0.4	<0.1	<0.1

Table 17

Ammonia (mg/L-N) Values for the Cedar River near the Duane Arnold Energy Center During 1992

	Sampling Locations				
Date 1992	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-08	<0.1	<0.1	0.1	<0.1	0.1
Jan-23	<0.1	<0.1	<0.1	<0.1	<0.1
Feb-05	0.3	0.3	0.3	0.3	0.4
Feb-20	0.7	0.8	0.7	0.7	0.8
Mar-04	0.6	0.5	0.5	0.5	0.5
Mar-19	0.2	0.1	0.8	<0.1	0.6
Apr-01	<0.1	<0.1	0.1	<0.1	<0.1
Apr-16	<0.1	<0.1	<0.1	<0.1	<0.1
May-06	<0.1	<0.1	<0.1	<0.1	<0.1
May-20	0.2	0.1	0.2	0.1	0.1
Jun-04	<0.1	<0.1	0.1	<0.1	<0.1
Jun-18	<0.1	<0.1	0.1	<0.1	0.1
Jul-01	0.2	<0.1	<0.1	<0.1	0.2
Jul-16	<0.1	<0.1	0.1	<0.1	<0.1
Aug-06	<0.1	<0.1	0.1	<0.1	<0.1
Aug-20	<0.1	<0.1	<0.1	<0.1	<0.1
Sep-03	<0.1	<0.1	<0.1	<0.1	<0.1
Sep-16	<0.1	<0.1	<0.1	<0.1	<0.1
Oct-01	<0.1	<0.1	0.1	<0.1	<0.1
Oct-14	<0.1	<0.1	0.1	<0.1	<0.1
Nov-05	<0.1	<0.1	<0.1	<0.1	<0.1
Nov-18	0.2	0.1	0.2	0.1	0.2
Dec-03	<0.1	<0.1	0.3	<0.1	<0.1
Dec-16	0.2	0.2	0.5	0.2	0.2

Table 18

Nitrate (mg/L-N) Values for the Cedar River near the Duane Arnold Energy Center During 1992

Date 1992	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-08	8.6	8.7	7.8	8.8	8.8
Jan-23	9.7	9.7	10	10	9.8
Feb-05	6.5	6.5	6.7	6.7	6.6
Feb-20	3.8	3.9	3.9	3.9	4.0
Mar-04	5.1	4.9	4.9	4.9	4.9
Mar-19	9.1	9.1	7.9	9.3	9.0
Apr-01	8.3	8.3	7.0	8.2	8.4
Apr-16	7.4	7.4	6.4	7.4	7.5
May-06	8.1	8.1	29	8.3	8.2
May-20	6.7	6.6	24	6.8	6.7
Jun-04	7.4	7.3	28	7.4	7.5
Jun-18	5.2	5.4	19	5.6	5.4
Jul-01	5.9	5.8	24	5.8	5.7
Jul-16	7.4	7.1	18	7.2	7.3
Aug-06	7.2	6.9	24	6.9	7.0
Aug-20	4.2	4.1	3.6	4.0	4.0
Sep-03	2.6	2.5	2.6	2.5	2.5
Sep-16	3.2	3.1	11	3.1	3.2
Oct-01	4.4	4.3	14	4.7	4.3
Oct-14	3.8	3.2	10	3.2	3.2
Nov-05	6.9	6.7	15	6.8	6.8
Nov-18	7.1	7.1	15	7.2	7.2
Dec-03	8.5	8.6	8.0	8.6	8.6
Dec-16	7.5	7.4	5.1	7.4	7.4

Table 19

Total Iron (mg/L) Values for the Cedar River near the Duane Arnold Energy Center During 1992

Date 1992	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-08	0.29	0.31	0.22	0.32	0.34
Jan-23	0.19	0.15	0.19	0.15	0.16
Feb-05	0.83	0.86	1.0	0.90	1.0
Feb-20	1.6	1.6	1.6	1.6	1.5
Mar-04	0.62	0.65	0.80	0.65	0.67
Mar-19	0.61	0.63	0.55	0.61	0.57
Apr-01	0.61	0.61	0.46	0.65	0.63
Apr-16	0.29	0.32	0.41	0.32	0.38
May-06	0.44	0.32	1.8	0.39	0.47
May-20	2.0	2.0	2.6	1.8	1.9
Jun-04	0.53	0.53	2.2	0.56	0.54
Jun-18	0.50	0.43	0.94	0.46	0.49
Jul-01	1.1	0.92	2.9	0.98	1.0
Jul-16	1.5	1.4	4.7	1.4	1.3
Aug-06	0.55	0.60	2.3	0.56	0.70
Aug-20	0.56	0.58	0.91	0.63	0.64
Sep-03	0.33	0.40	0.26	0.36	0.34
Sep-16	0.38	0.48	1.2	0.51	0.41
Oct-01	0.23	0.29	1.0	0.31	0.33
Oct-14	0.27	0.21	0.69	0.22	0.24
Nov-05	1.5	1.4	2.4	1.4	1.3
Nov-18	0.29	0.28	0.76	0.31	0.31
Dec-03	0.32	0.33	0.20	0.32	0.31
Dec-16	0.43	0.41	0.48	0.41	0.41

Table 20

Biochemical Oxygen Demand (5-day in mg/L) Values for the Cedar River near the Duane Arnold Energy Center During 1992

	Sampling Locations				
Date 1992	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-08	2	2	2	2	2
Jan-23	1	<1	<1	1	1
Feb-05	3	3	4	4	4
Feb-20	7	7	8	8	8
Mar-04	8	7	9	8	8
Mar-19	<1	1	<1	<1	1
Apr-01	3	3	2	3	2
Apr-16	3	3	2	3	3
May-06	6	6	16	6	6
May-20	5	5	16	5	5
Jun-04	7	8	18	8	8
Jun-18	6	7	12	7	7
Jul-01	10	10	19	10	10
Jul-16	3	2	5	3	3
Aug-06	5	5	12	5	5
Aug-20	12	12	8	11	12
Sep-03	16	18	16	17	17
Sep-16	9	10	25	11	11
Oct-01	8	8	14	10	10
Oct-14	8	9	16	8	9
Nov-05	6	5	13	7	7
Nov-18	1	1	1	<1	<1
Dec-03	1	1	1	<1	<1
Dec-16	2	5	<1	2	2

Table 21

Coliform Bacteria (Fecal Organisms/100 ml) Values for the Cedar River near the Duane Arnold Energy Center During 1992

Date 1992	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-08	660	490	210	560	580
Jan-23	260	100	150	130	270
Feb-05	720	630	470	520	550
Feb-20	2600	2800	2600	3000	1700
Mar-04	60	70	50	50	60
Mar-19	200	130	100	160	80
Apr-01	40	70	20	20	40
Apr-16	100	110	60	80	40
May-06	10	10	150	20	10
May-20	940	650	680	600	190
Jun-04	30	20	120	20	30
Jun-18	90	70	600	140	100
Jul-01	60	20	100	10	20
Jul-16	1700	1300	3300	1900	1200
Aug-06	350	330	70	390	260
Aug-20	70	60	180	90	80
Sep-03	230	210	210	260	170
Sep-16	1000	400	1300	300	300
Oct-01	30	60	320	80	20
Oct-14	50	50	120	20	50
Nov-05	6900	6500	730	7800	6300
Nov-18	260	100	90	140	100
Dec-03	550	530	1400	440	290
Dec-16	3700	4400	480	4900	3300

Table 22

Coliform Bacteria (E. coli/100 ml) Values for the Cedar River near the Duane Arnold Energy Center During 1992

Date 1992	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan-08	790	690	170	620	490
Jan-23	200	50	100	130	120
Feb-05	640	440	500	520	650
Feb-20	1900	1100	1000	1900	1300
Mar-04	50	30	90	50	80
Mar-19	160	140	130	180	180
Apr-01	50	20	20	40	50
Apr-16	60	80	40	80	70
May-06	30	40	260	30	20
May-20	1100	760	690	480	190
Jun-04	20	20	130	30	<10
Jun-18	90	140	400	90	20
Jul-01	40	20	1000	10	20
Jul-16	1500	2300	3700	1800	1200
Aug-06	310	330	40	380	390
Aug-20	120	30	220	80	130
Sep-03	250	250	220	240	230
Sep-16	550	460	1400	390	520
Oct-01	40	10	340	60	10
Oct-14	50	60	210	30	80
Nov-05	6700	6000	410	5800	7700
Nov-18	200	100	50	180	130
Dec-03	450	330	1200	380	300
Dec-16	3400	3200	430	3600	3300

Table 23

Additional Chemical Analysis-1992

Station	Cl^- (mg/L)	SO_4^{-2} (mg/L)	Metals (ug/L) Cr	Cu	Pb	Mn	Hg	Zn
			Apr-01					
1. Lewis Access	22	29	<20	30	<10	30	<1	<20
2. Upstream DAEC	22	34	<20	40	<10	40	<1	<20
3. Downstream DAEC	21	32	<20	30	<10	30	<1	<20
4. One-half mile below plant	22	39	<20	40	<10	30	<1	<20
5. Discharge Canal	20	27	<20	50	<10	30	<1	<20
			Jul-01					
1. Lewis Access	26	33	<20	<10	20	80	<1	<20
2. Upstream DAEC	26	38	<20	<10	<10	80	<1	<20
3. Downstream DAEC	26	31	<20	<10	<10	80	<1	<20
4. One-half mile below plant	24	37	<20	20	<10	80	<1	<20
5. Discharge Canal	110	870	<20	40	<10	220	<1	900

Table 24

Benthic macroinvertebrates collected on Hester-Dendy artificial substrates from the Cedar River and the discharge canal in the vicinity of the Duane Arnold Energy Center, May 20-July 1, 1992.

Taxon	Lewis Access	U/S DAEC	Collection Site D/S DAEC	½ mi below plant	Disc. Canal
Arthropoda					
Insecta					
Coleoptera (Beetles)					
Elmidae					
Macronychus sp.		1	2	1	
Stenelmis sp.			2	2	
Diptera					
Ceratopogonidae					
Stilobezzia sp.	4				
Chironomidae	7632	7905	6144	6432	10
Simuliidae					
Simulium sp.	48	1	2	1	24
Empididae					
Hemerodromia sp.	88	5	11	7	
Ephemeroptera (Mayflies)					
Baetidae	4	2	1		
Baetis sp.	28	24	16	45	
Caenidae					
Caenis sp.	12	6	6	41	
Heptageniidae					
Heptagenia sp.	16	15	13	23	2
Stenonema sp.	12	9	6	6	
Oligoneuriidae					
Isonychia sp.	140	229	143	221	
Polymitarcidae					
Ephoron sp.				3	
Tricorythidae					
Tricorythodes sp.		3	26	6	
Plecoptera (Stoneflies)					
Perlidae					
Acroneuria sp.			1		
Perlesta sp.	4	11	5	9	
Trichoptera (Caddisflies)					
Hydropsychidae (larvae/pupae)	102	224	148	344	7
Cheumatopsyche sp.	12	8	8		1
Hydropsyche bidens	356	516	412	464	2
Hydropsyche orris	144	52	28	60	
Hydropsyche simulans	176	44	60	108	1
Hydropsyche sp.	48	24	4	8	
Potamyia sp.	140	72	92	96	
Molluska					
Gastropoda					
Limnophila					
Physidae					
Physa sp.					797
Platyhelminthes					
Turbellaria					
Tricladida					
Planariidae					138
Total Organisms	8966	9150	7130	7887	982

Note: to convert no. of organisms counted to No./m^2 multiply by 6.25.
Prepared by UHL Limnology Section

Table 24 (con't.)

Benthic macroinvertebrates collected on Hester-Dendy artificial substrates from the Cedar River and the discharge canal in the vicinity of the Duane Arnold Energy Center, August 20-October 1, 1992.

Taxon	Lewis Access	U/S DAEC	Collection Site D/S DAEC	½ mi below plant	Disc. Canal
Arthropoda					
Insecta					
Coleoptera (Beetles)					
Elmidae					
Stenelmis sp.		14	2	2	1
Dryopidae					
Helichus sp.		2			
Diptera					
Chironomidae	19968	1312	2608	3808	1
Simuliidae					
Simulium sp.	582	47	10	120	1
Empididae	448		16	8	
Hemerodromia sp.		1	50	44	
Ephemeroptera (Mayflies)					
Baetidae					
Baetis sp.	4	15	6	22	
Caenidae					
Caenis sp.				2	
Heptageniidae	14	57		2	
Heptagenia sp.	34	58	46	90	
Stenonema sp.	16	195	138	144	
Leptophlebiidae		3			
Oligoneuriidae					
Isonychia sp.	2	23	2	12	
Tricorythidae					
Tricorythodes sp.	4	7	6		
Plecoptera (Stoneflies)	2	5	2	6	
Perlidae					
Perlesta sp.	6			2	
Odonata					
Coenagrionidae					
Argia sp.			2		5
Trichoptera (Caddisflies)					
Hydropsychidae (larvae & pupae)	342	198	142	319	1
Ceratopsyche bifida			1		
Cheumatopsyche sp.	8	6	6	2	
Hydropsyche bidens	366	542	328	842	
Hydropsyche orris	32	13	14	36	
Hydropsyche simulans	98	185	110	222	
Hydropsyche sp.	2	4		2	
Potamyia sp.	156	22	164	86	
Molluska					
Gastropoda					
Limnophila					
Physidae					
Physa sp.			14		743
Annelida					
Oligochaeta					9
Platyhelminthes					
Turbellaria					
Tricladida					
Planariidae			14	2	21
Total Organisms	22084	2709	3681	5773	782

Table 25

Daily Numbers of Fish Impinged at the Duane Arnold Energy Center
January-December 1992

Day of the Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3	2	1	8	1	0	0	0	1	0	0	2
2	2	1	0	11	0	0	0	0	0	0	0	1
3	5	2	0	11	2	0	0	0	0	0	2	0
4	16	3	3	4	1	1	0	0	0	0	0	0
5	0	5	1	9	3	0	1	0	0	0	0	1
6	0	2	0	6	0	1	0	0	0	0	0	0
7	7	0	2	2	1	0	0	0	0	1	1	0
8	1	21	0	9	0	1	0	0	0	0	0	5
9	2	5	3	7	0	0	0	1	0	0	1	9
10	4	2	0	7	0	0	0	0	0	0	0	1
11	3	5	0	12	0	0	0	0	0	0	0	0
12	1	1	0	5	0	0	0	0	1	0	0	1
13	3	2	0	11	0	0	1	0	1	0	1	0
14	2	5	0	7	1	1	0	0	0	0	0	1
15	1	3	1	14	0	1	1	0	0	0	0	0
16	0	0	1	6	0	1	1	0	0	0	3	2
17	1	2	2	4	0	1	1	0	0	0	0	1
18	1	5	3	3	0	0	0	0	0	0	0	1
19	1	10	0	5	0	0	0	0	0	1	0	1
20	0	0	0	6	0	0	0	0	0	3	1	2
21	1	10	0	6	0	0	0	0	0	1	1	1
22	0	1	2	1	0	1	1	0	0	0	2	4
23	1	4	2	1	1	1	0	0	0	1	0	1
24	2	12	2	1	0	1	0	0	0	0	0	3
25	0	8	3	1	0	0	0	0	0	0	0	1
26	1	10	5	3	0	0	0	0	0	0	1	1
27	3	13	2	3	0	0	1	0	0	0	0	0
28	6	8	3	0	0	0	0	0	0	0	1	2
29	0	8	5	0	0	0	0	0	0	0	3	1
30	3		3	0	0	0	0	1	0	0	0	0
31	4		4		0		0	0		0		0
Total	74	150	48	163	10	10	7	2	2	7	17	42

Annual Total	532

Table 26

Comparison of Average Values for Several Parameters at Upstream, Downstream, and Discharge Canal Locations at the Duane Arnold Energy Center During Periods Of Station Operation*-1992

Parameters	Upstream (Sta. 2)	Discharge Canal (Sta. 5)	Mixing Zone (Sta.3)	Downstream (Sta.4)
Temperature (°C)	12.2	17.2	12.4 (102)*	12.6 (103)*
Dissovled Solids (mg/L)	292	1065	304 (104)	298 (102)
Total Hardness (mg/L)	261	765	272 (104)	268 (103)
Total Phosphate (mg/L)	0.32	1.4	0.33 (103)	0.31 (97)
Nitrate (mg/L as N)	6.3	14.4	6.3 (100)	6.3 (100%)
Iron (mg/L)	0.68	1.4	0.68 (100)	0.69 (101%)

*Percent of upstream level ()

Table 27

Comparison of Average Yearly Values for Several Parameters in the Cedar River Upstream of the Duane Energy Center*
1972-1992

Year	Mean flow** (cfs)	Turbidity (NTU)	Total PO_4 (mg/L)	Ammonia (mg/L-N)	Nitrate (mg/L-N)	BOD (mg/L)	Total Hardness (mg/L)
1972	4,418	22	1.10	0.56	0.23	5.7	253
1973	7,900	28	0.84	0.36	1.5	4.0	250
1974	5,580	29	2.10	0.17	4.2	4.7	266
1975	4,206	58	1.08	0.33	2.8	6.5	251
1976	2,082	41	0.25	0.25	2.8	7.3	233
1977	1,393	15	0.33	0.52	2.9	6.5	243
1978	3,709	23	0.26	0.22	4.4	3.3	261
1979	7,041	26	0.29	0.12	6.6	2.5	272
1980	4,523	40	0.34	0.19	5.4	4.3	238
1981	3,610	33	0.77	0.24	6.0	6.5	279
1982	7,252	43	0.56	0.23	8.0	5.1	274
1983	8,912	22	0.25	0.10	8.6	3.3	259
1984	7,325	40	0.32	0.10	5.9	3.9	264
1985	3,250	30	0.31	0.11	4.8	6.7	245
1986	6,375	33	0.26	0.10	6.8	3.7	285
1987	2,625	32	0.24	0.06	5.6	5.8	269
1988	1,546	28	0.30	<0.16	2.8	9.6	246
1989	947	24	0.37	0.30	1.5	10.3	224
1990	5,061	33	0.29	0.20	7.3	4.8	283
1991	8,085	65	0.38	0.20	7.9	4.3	268
1992	5,717	49	0.31	0.16	6.4	5.5	261

*Data from Lewis Access location (Station 1)
**Data from U.S. Geological Survey Cedar Rapids gauging station

Table 28

Summary of Relative Loading Values (Average Annual Concentration x Cumulative Runoff) for Several Parameters in the Cedar River Upstream of the Duane Energy Center*
1972-1992

Year	Mean Flow (cfs)	Cumulative** Runoff (in)	Turbidity	Relative Loading Values Total PO	Ammonia	Nitrate	BOD
1972	4,418	9.24	203	10.2	5.2	2	53
1973	7,900	16.48	461	13.8	5.9	25	66
1974	5,580	11.64	338	24.4	2.0	49	55
1975	4,206	8.77	509	9.5	2.9	25	57
1976	2,082	4.35	178	1.1	1.1	12	32
1977	1,393	2.91	44	1.0	1.5	8	19
1978	3,709	7.74	178	2.0	1.7	34	26
1979	7,041	14.79	385	4.3	1.8	98	37
1980	4,523	9.45	378	3.2	1.8	51	41
1981	3,610	7.53	248	5.8	1.8	45	49
1982	7,252	15.13	651	8.5	3.5	121	77
1983	8,912	18.00	396	4.5	1.8	155	59
1984	7,325	15.22	609	4.9	1.5	90	59
1985	3,250	6.80	204	2.1	0.8	33	46
1986	6,475	13.11	433	3.4	1.3	89	49
1987	2,625	4.85	155	1.2	0.3	27	28
1988	1,546	2.85	80	0.9	<0.4	8	27
1989	947	1.84	44	0.7	0.6	3	19
1990	5,061	9.34	308	2.7	1.9	68	45
1991	8,085	17.15	1115	6.5	3.4	135	74
1992	5,717	10.92	535	3.4	1.7	70	61

*Data from Lewis Access location (Station 1)
**Data from U.S. Geological Survey Cedar Rapids gauging station